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Mitigation of Attentional Tunneling in the Flight Deck using a Spatial Auditory Display

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Acronyms and Definitions

ARC .... Ames Research Center
ASOP .... Airspace Operations and Safety Program
ASRS .... Aviation Safety Reporting System
dB .... decibel
dBA..................................... A-weighted sound level
HRIRB .... Human Research Institutional Review Board
HRTF .... head related transfer function
NASA .... National Aeronautics and Space Administration
r.m.s. .... root mean square
s .... seconds
SD....................................... Standard deviation
SE .... Standard error
NTSB .... National Transportation Safety Board

Mitigation of Attentional Tunneling in the Flight Deck using a Spatial Auditory Display

Giovanna Guevara[1], Durand R. Begault[2],
Kaushik Sunder[3], and Mark Anderson[4]

The role of attentional bias to a specific form of information, e.g., visual versus aural instructions, was evaluated to address the issue of attentional fixation (i.e., "cognitive tunneling") in the flight deck. A method of mitigating attentional tunneling using a spatial auditory display was evaluated in the presence and absence of a biasing factor. Data were gathered for participant recognition, accuracy and response times to aural and visual instructions under different conditions of distractor stimuli. Results showed a significant main effect for target acquisition with the use of spatial audio techniques. No significant main effects or interactions were found for target acquisition timing. Target acquisition was not affected by a "gaming score" biasing factor associated with the distractor tasks.

1. Introduction

Attentional tunneling is defined as the allocation of attention to a particular channel of information, diagnostic hypothesis, or task goal, for a duration that is longer than optimal, given the expected cost of neglecting events on other channels, failing to consider other hypotheses, or failing to perform other tasks[5]. The phenomenon has been referred to in the literature as "cognitive fixation" or "cognitive capture" and is related to the phenomenon of "inattentional blindness" for unexpected visual events. The U.S. National Transportation Safety Board (NTSB) states that approximately half of commercial air accidents can be attributed to human error caused by inattention of the crew[6]. For example, the Eastern Airlines accident in 1972 was caused by preoccupation of the crew on a landing gear problem while ignoring auditory warnings regarding descent[7].

Research of pilot error has generally focused on perceptual load, automation, and displays of cockpit information—as well as the negative impact they may have on the pilot and their attention to a specific problem. The accuracy and efficiency by which aural and visual display messages are

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[4] ASRC Research and Technology; Moffett Field, CA.

[5] C.D. Wickens and A.L. Alexander. (2009) "Attentional Tunneling and Task Management in Synthetic Vision Displays," *International Journal of Aviation Psychology*, 19:2, pp. 182–199.
[6] National Transportation Safety Board. (1994) "A review of flight crew-involved major accidents of U.S. air carriers, 1978 through 1990," NTSB/SS-94-01.
[7] National Transportation Safety Board. (1974) Aircraft Accident Report NTSB-AAR-73-14 (1974).

recognized and the controls are set in response can be biased towards specific stimuli by providing feedback. This represents an experimentally controllable form of the "attentional tunneling" phenomenon addressed in our prior research[8]. The use of virtual acoustic techniques has also been shown in previous work to improve detection of auditory alarm stimuli[9].

The current study explored if the use of a relatively simple spatial auditory display would significantly mitigate attentional tunneling in the presence of multiple distractor tasks and under conditions where a biasing factor was present or absent. We hypothesized that the use of an auditory analogue to a visual alert "pop out"[10] effect using color could be effected by having auditory targets routed to a unique position in auditory space relative to non-target auditory data. Data were gathered for aural target acquisition accuracy and response times under different conditions of distractor stimuli. The distractors included a visual target acquisition task, and a manual task where a virtual dial was set to a numeric value based on a presented instruction.

2. Method

2.1 Participants

Fourteen volunteer participants (age range 20–40) were recruited from within National Aeronautics and Space Administration (NASA) Ames Research Center (ARC). All participants had self-reported normal or corrected to normal vision and normal hearing. The experiment protocol was conducted with approval from the ARC Human Research Institutional Review Board (HRIRB). Participants volunteered to participate and received approval from supervisors. 12 of the 14 participants completed the entire experiment; post-hoc analysis showed that the presence or absence of finished blocks from the other two subjects had no significant impact on the overall conclusions of this report[11].

2.2 Experimental Design

The experiment was designed to determine if there was a significant difference between two modes of audio target presentation (spatialized "pop out" from other audio radio communications, versus single channel audio) for target acquisition in the presence of simultaneous distractor tasks. The distractor tasks were (1) manual response to a visual target, (2) manual rotation of a virtual control dial to a visually presented numeric value, and (3) presence or absence of a biasing factor (a visual score that increased with each successful distractor task accomplished). The hypothesis tested was that the use of spatialized audio would improve audio target acquisition time and accuracy, independent of the type of distractor condition tested.

The dependent variables evaluated were audio target acquisition accuracy (hit, miss, correct rejection and false alarm rates) and audio target timing (time interval between audio signal and finger response on a touchscreen). The independent variables were distractor type, audio presentation mode, and biasing factor. Eight experimental blocks representing each of the unique combination of distractor and audio presentation conditions was evaluated for each subject, using a

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[8] Begault, D.R., Christopher, B.R., Zeamer, C., Anderson, M.R., and Guevara Flores, G. (2016) A Touchpad-Based Method for Inducing Attentional Tunneling. NASA Technical Memorandum 2016–219208.
[9] Begault, D.R., Anderson, M.R., and McClain, B.M. (2006) Spatially-modulated auditory alerts for aviation. *Journal of the Audio Engineering Society* 55:4, pp. 276–282.
[10] Visual "pop-out" refers to the psychological phenomenon in which a unique visual target can be rapidly detected among a set of homogeneous distractors. Ref. Treisman, A.M., & Gelade, G. (1980) A feature integration theory of attention. *Cognitive psychology*, 12, 97–136.
[11] Supplemental analyses were performed using the grand mean for missing data cells in the incomplete participant blocks.

within-subjects design paradigm with randomized blocks (Table I). These are referred to hereafter as the "balanced" blocks of the experiment.

Table I. Balanced Blocks

Block	*Audio Target Presentation*	*Distractor Task*	*Biasing Factor*
1	Single channel	Visual target response	Present
2	Spatial audio	Visual target response	Present
3	Single channel	Virtual dial	Present
4	Spatial audio	Virtual dial	Present
5	Single channel	Visual target response	Absent
6	Spatial audio	Visual target response	Absent
7	Single channel	Virtual dial	Absent
8	Spatial audio	Virtual dial	Absent

In addition, four additional blocks representing baseline conditions were evaluated for each participant. These are referred to as the "control" blocks of the experiment; ref. Table II. Two of the control blocks (blocks 9 and 10) represented a "minimum" workload condition compared to the balanced blocks, contrasting the effect of audio presentation mode (single-channel or spatial audio) in the absence of a distractor task or biasing factor. The other two control blocks (blocks 11 and 12) represented a "maximum" workload condition compared to the balanced blocks, contrasting the effect of audio presentation mode with both distractor tasks and the biasing factor present.

Table II. Control Blocks

Block	*Audio Target Presentation*	*Distractor Task*	*Biasing Factor*
9	Single channel	None	Absent
10	Spatial audio	None	Absent
11	Single channel	Visual dial ***and*** visual target	Present
12	Spatial audio	Visual dial ***and*** visual target	Present

2.3 Participant Preparation

Prior to running the experiment, participants were screened via a questionnaire for hearing or visual impairment as well as for temporary threshold shifts from recent noisy activity. An experiment proctor reviewed written instructions with the participant and then administered a set of four two-minute training blocks that served to introduce the tasks and to provide the proctor with an observational check that the instructions were understood. These were shortened versions of blocks 9, 1, 3 and 11, representing increasing levels of difficulty. Participants were not informed in advance of the use of spatial audio in the main experiment; all training blocks were single channel audio. Participants were instructed to make their responses as accurately and as quickly as possible to both auditory and visual stimuli.

Following this, the main experiment began, with the 12 total balanced and control blocks presented in unique randomized order to each subject. The time to complete all of the blocks including training, rest periods and computer setup was ~2.5 hours. Each block took ~5 minutes to complete. Breaks were allowed between each block.

3. Stimuli

3.1 Presentation Context

Stimuli were presented to participants in the context of a pseudo-flight deck environment with information displays, control panels, radio communications, and flight deck background noise, simulated using a combination of loudspeakers, touchpad surfaces, and a computer display. Acoustic stimuli included simulation of the background noise of a commercial airliner flight deck, communications from ground control, and an auditory chime for interactive feedback. Visual stimuli include a text display of instructions for setting the controls on a touchpad screen; a virtual dial manipulated using a second touchpad screen; and a computer display with a virtual "check pilot."

Figure 1 shows a photo of the experiment setting. Participants were seated at a table within the Advanced Displays and Controls Laboratory at NASA Ames Research Center, at the location of the pictured dummy-head microphone in Figure 1. A set of nine loudspeakers surrounded the seating location (five full-range loudspeakers and four subwoofers) to provide an immersive background noise level representing an aircraft flight deck. Two additional "radio communication" loudspeakers were located at the sides of the large computer monitor at a distance of ~34 inches (shown with red arrows in Figure 1) and were used to generate spatialized or single channel auditory targets. All radio communications emanated from the left hand loudspeaker, with the exception of the spatialized audio target, which emanated from the right hand loudspeaker.

One touchpad was used to generate and present an instruction for the virtual dial task. The touchpad display had an opaque covering that only allowed a single instruction line of text to appear (ref. Figure 2, left). The font was green colored DIN alternate bold 32 pt. to imitate the text of a commercial airliner flight management display. The other touchpad (ref. Figure 2, right) was used to generate visual targets (the word ALERT); the virtual dial (manipulated by touching the white dot until the value is set per the instruction); and the response to the audio target (by touching the up arrow for a "climb" instruction, the down arrow for a "descend" instruction, the left arrow for a "turn left" instruction and the right arrow for a "turn right" instruction).

Figure 1. Experiment location with loudspeakers and touchpad displays. The numerical score (not shown) for the bias conditions is located at center bottom of the large display with the check pilot.

Figure 2. Left: instruction given on touchpad display indicated in Figure 1 by yellow arrow. Right: display on touchpad indicated in Figure 1 by green arrow.

Present throughout each block of the experiment was a pre-recorded looped video of a uniformed check pilot presented on a 27-inch computer display located behind the touchpads (Figure 1). The check pilot was made to appear as if he was an interested observer watching the actions of the participants during each block[12].

3.2 Auditory Stimuli

A randomized set of 200 pre-recorded target and non-target radio communications were played sequentially throughout each block, consisting of a sequence of company identifier, call sign, and instruction; e.g., "Delta 186, climb to flight level 2–7–0" or "FedEx 506, turn left heading 9–0." The randomization of targets and non-targets was unique within each block. Twenty of the 200 radio communications were target stimuli.

Four different synthesized speech voices (two female, two male) were used; each utterance was scaled to be ~2.5 s in duration using a time stretch-compression algorithm and normalized to the same r.m.s. amplitude value within waveform editing software. The playback level was ~75 dB(A). Non-target audio communications all emanated from the left side loudspeaker (left red arrow in Figure 1). Throughout each block, the background noise recorded from the interior of a Boeing 737-300 in level flight was presented at a level of ~65 dB(A) from the nine loudspeakers of the surround sound system.

The radio communication target requiring a response was the call sign for the participant's ownship, "United 972," followed by an instruction to either turn left, turn right, climb, or descend. For the single channel block conditions (block numbers 1, 3, 5, 7, 9, and 11) the target emanated from the same left side loudspeaker as the non-target radio communications. For the spatial audio conditions (block numbers 2, 4, 6, 8, 10 and 12), the target was instead routed to the right side loudspeaker (right red arrow in Figure 1), also at a level of ~ 75 dB(A). This caused the perceived spatial localization of the target to appear ~60 degrees right of the median sagittal plane in virtual space, as opposed to ~60 degrees leftwards for the non-target audio. The physical acoustic cues responsible for the differences in perceived position interpreted by the binaural hearing system are the resulting interaural time and level differences at the ears[13].

3.3 Visual and Manual Distractor Stimuli

There were three distractor conditions, where participants were alerted to perform a task in conjunction with attending to the radio communication channel for audio target acquisition:

- a visual target acquisition task (the text ALERT presented on a display virtual button for 2 seconds; the task is to respond by touching the button) (blocks 1, 2, 5 and 6)
- a visual-manual task (the text "SET KNOB TO XXX" with XXX a number between 0 and 359 presented on the second touchpad display; the task is to set a virtual dial to that position on a second display) (blocks 3, 4, 7, 8)
- both visual tasks interleaved randomly (blocks 11–12)

[12] In prototype versions of the experiment, the check pilot would also provide positive or negative verbal feedback and visual feedback, based on performance of the distractor tasks. This was not ultimately used to prevent masking of the radio communication channel.

[13] Begault, D.R. (1994) *3-D Sound for Virtual Reality and Multimedia*. Cambridge, MA: Academic Press Professional.

There was a total of 90 visual and 50 visual-manual distractor tasks distributed randomly across the 5 min duration of each block, depending on the distractors used in the specific block (reference Tables I and II).

3.4 Biasing Factor

The biasing factor was a visual representation of a numeric score that increased with successful accomplishment of either distraction task, along with a brief affirmative audio signal (sound of a cash register bell). An integer (2.5" vertical white Helvetica font) was placed within a 10 1/8" x 4 1/16" red square located ~40" from the participant, at the bottom of the check pilot computer display, ref. Figure 3. The integer was set initially at a score value of zero. During blocks that included a biasing factor (blocks 1-4, 11-12), this score would increase in a pseudo-random manner with each successful completion of the distraction task, much in the manner of a computer game. The value reset to zero with the start of each block. The participant was asked to note the score on a pad of paper after each block, to encourage their involvement in the distractor task. (These written scores were destroyed at the end of the experiment and were not used in the data analysis).

Figure 3. Example of score display located at bottom of check pilot computer display.

3.5 Experimental Block Generation, Scoring

A script-generation algorithm was developed to generate a sequence of timed target and distractor events for each block (written using MathWorks MATLAB). The algorithm used a rectangular distribution function to determine randomized timing onsets of stimuli, based on a total number of indicated events. Timings were constrained by a minimum interval to ensure hearing the entirety of radio communications and allow adequate time for a response before the next type of event. The minimum interval for radio communications (target and non-target audio) was 3 seconds; for virtual dial instructions, 5 seconds; for visual targets, 2 seconds. The virtual dial instruction remained displayed until the next virtual dial instruction appeared. Figure 4 shows a time history of stimuli presentation for a portion of block 11.

The virtual dial distractor task was considered a "miss" when a response did not occur within the time period prior to the next activated stimulus. The visual target remained present for a maximum of 2 seconds and was considered a "miss" if not responded to within that time. The virtual dial task was considered a hit if the correct value was dialed to match the instruction and the participant's finger was removed before the appearance of the following instruction. The virtual dial task was scored as a miss if no response was given to the instruction, if the participant dialed in the wrong value and removed their finger, or if the participant's finger still remained on the dial when the next instruction appeared. "False Alarms" were scored when the alert or dial was touched when no instruction was given or when touched more than once after an initial instruction was completed.

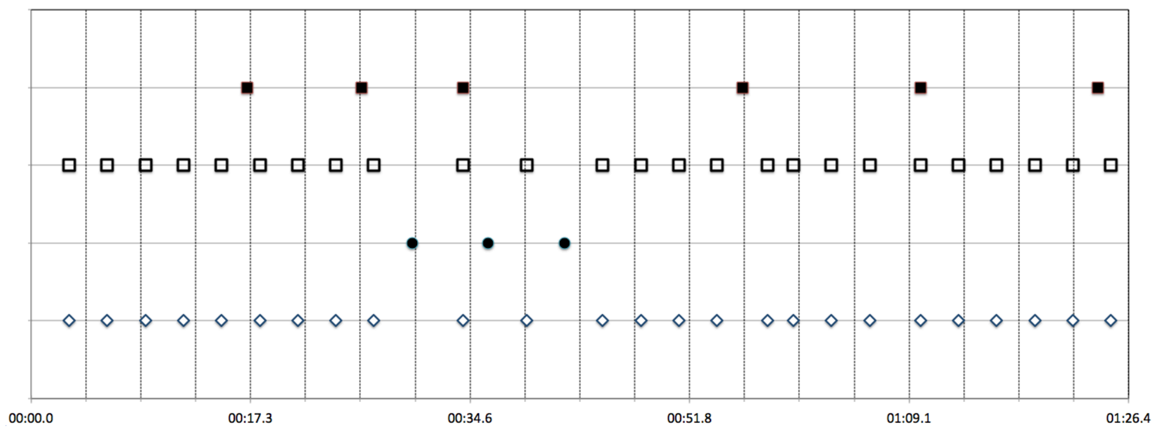

Figure 4. Visual representation of stimulus presentation in a portion of a block from the script generation algorithm (first 1.26 s of block 11 from Table II). Horizontal axis indicates time: seconds, with ~4.3 s between each vertical line. Legend: unfilled diamond = non-target radio communication; filled circle = target radio communication; unfilled square = visual distractor target; filled square = dial command.

Auditory targets were scored in terms of both hit rate and accuracy. If the participant responded to the auditory target (ownship radio communication), it was scored as a "hit," regardless of touching the appropriate arrow for "climb," "descend," "turn left," or "turn right" instruction. The response was scored as an "accurate hit" when the response matched the instruction and was subsequently analyzed as "accuracy." The analysis that follows focuses on accuracy as opposed to overall hit rate.

The files generated by the script generation program were labeled and assigned randomly to each subject. The script was then read by custom experiment software that executed the stimuli for each block (Cycling74 MAX 7). The software played back audio stimuli to assigned loudspeaker channels and communicated with each touchpad to both send stimuli and receive response data, via a local area Wi-Fi network. Timing data were referenced to the touchpad clock that recorded time elapsed between a response and an instruction. At the end of each block, an output file was generated showing the input script parameters interleaved with the response data.

4. Results

4.1 Experiment 1: Balanced Blocks, Accuracy

A three-way analysis of variance (audio display x distractor type x biasing factor) was used to analyze the balanced blocks. The results showed a significant effect of audio presentation mode on accuracy of response to the auditory task, ($F(1, 11) = 22.03$, $p = .001$), with spatial processing resulting in fewer missed targets (2.1 % versus 7.4 %); ref. Figure 5. There was no significant effect of audio presentation mode for visual task hit rate ($F(1,11) = 0.660$, $p = 0.420$) or the distractor task ($F(1,11) = 0.204$, $p = 0.653$). Means are shown in Table III. A low false alarm rate was found for all tasks (Table IV).

A sign-test was used to confirm the main effect of audio presentation mode on response accuracy: for spatialized audio, accuracy showed a statistically significant increase, ($z = -3.903$, $p < 0.001$).

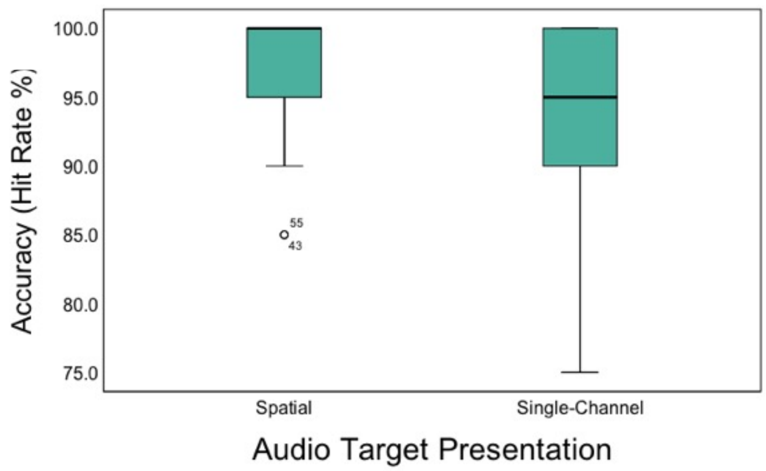

Figure 5. Significant effect for audio target accuracy as a function of presentation mode (spatial versus single channel) in balanced-block tasks.

Table III. Accuracy (percent correct)

Task	*Single Channel*	*Spatialized*
Auditory	92.50	97.25
Visual	97.34	98.14
Virtual dial	89.79	91.01

Table IV. False Alarm (mean percent)

Task	*N*	*Min*	*Max*	*Mean*
Auditory	112	0	3	0.31
Visual	56	0	7	1.5
Virtual dial	56	0	6	1.5

4.2 Experiment 1: Balanced Blocks, Auditory Target Response Time

A three-way analysis of variance (audio display x distractor type x biasing factor) was used again to analyze the response time for these blocks. The timing data were normalized using a log-transform within SPSS. Untransformed data had a Kolmogoroff-Smirnoff skew value of -0.26 while transformed data had a skew value of 0.182. No significant effect was found between conditions for transformed data. The overall average reaction time for targets was 2.5 s (SD = 0.48 s; SE = 0.48 s)[14].

4.3 Experiment 2: Auditory Target Accuracy, Minimum Workload

A paired t-test was used to analyze the difference between audio presentations, but there was no significant difference in accuracy between single (M =96%, SD = 3.1%) and spatialized (M = 98%, SD = 3.1%) audio modality; ($t(12) = -1.555$, $p = 0.133$) under minimum workload conditions.

4.4 Experiment 2: Auditory Target Accuracy, Maximum Workload

A t-test was used to analyze the difference between audio presentations under maximum workload. Results showed a significant increase in accuracy from 91% in the single channel condition (SD = 7.1%) compared to 96% in the spatialized audio modality (SD = 3.7%, $t(12) = -2.413$, $p = 0.024$). Results are shown in Figure 6.

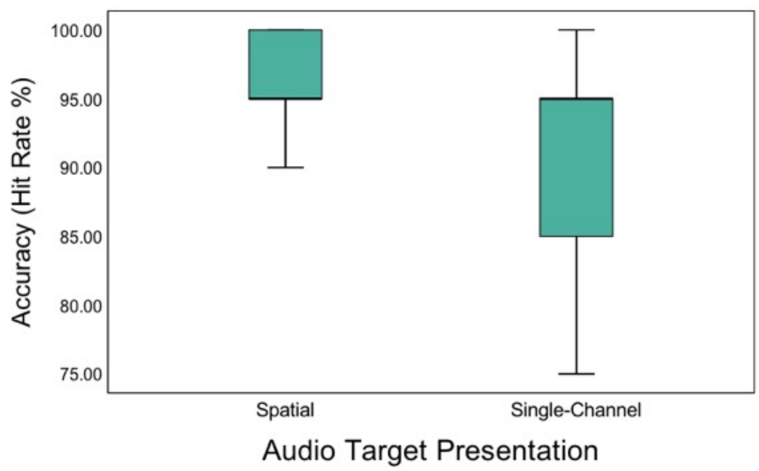

Figure 6. Significant effect for audio target accuracy as a function of presentation mode (spatial versus single channel) under maximum workload.

4.5 Experiment 2: Auditory Target Timing, Minimum Workload

A t-test was used to analyze the response time for the auditory target in the minimum workload conditions. The timing data were normalized using a log-transform within SPSS. Untransformed data had a KS skew value of 0.370 while transformed data had a skew value of 0.241. The average reaction time for targets was 2.4 s (SD = 0.2 s), but there was no significant difference between the single (x = 3.4s, SD = 0.043) and the spatialized (x = 3.3s, SD = 0.038) audio modality.

4.6 Experiment 2: Auditory Target Timing, Maximum Workload

A t-test was used to analyze the response time for the auditory target in the minimum workload conditions. The timing data were normalized using a log-transform within SPSS. Untransformed

[14] With all 14 subjects with missing data compensated, the average reaction time was 2.5 s (SD = 0.44, SE = 0.42).

data had a KS skew value of 0.060 while transformed data had a skew value of -0.207. The average reaction time for targets was 2.4 s (*SD* = 0.2 s), but there was no significant difference between the single (x = 3.39, *SD* = 0.039) and the spatialized (x= 3.30, *SD* = 0.036) audio modality.

5. Discussion

This study shows a significant advantage for spatial presentation of a speech-based audio target. When target speech signals for the participant's call sign were presented from a location different from other speech signals, detection improved on the order of 5 percent. The implication for the flight deck communications is a potential decrease in read-back errors. Analyses by NASA's Aviation Safety Reporting System (ASRS) self-report data from airmen and controllers have shown that read-back problems are caused by similar aircraft call signs, one pilot listening on a frequency, slips of mind and tongue, and expectancy factors[15].

We initially evaluated the use of head related transfer function (HRTF) filtering to implement a 3-D sound presentation of radio communications over headphones, an idea that had previously been presented as a comprehensive approach to an aviation auditory display[16]. We also evaluated the use of 3-D audio combined with cross-talk cancellation and acoustic beamforming techniques, which our prior research had demonstrated to be effective for improving speech intelligibility[17]. Ultimately, we chose the approach of a simple loudspeaker switching method so that the location of sound emanation was from an actual versus a virtual position, to avoid any confounds that the particular method of spatial synthesis may have imposed in this specific experiment (e.g., potential mismatch between a participant's HRTF and one used in synthesis). Nevertheless, we believe future implementations of an improved aviation auditory display could take advantage of headphone or beam-forming based spatial audio technologies.

Traditional single-frequency radio communications cannot easily accommodate a channel switching system that could switch and spatialize incoming communication to a specific location. However, the evolution of digital communication systems could allow metadata tagging of communications to an intended flight number via speech recognition of the controller, potentially allowing an advanced aircraft communication system to route communications appropriately.

The results presented here also show that an attentional tunneling effect could be imposed as a function of the presence of one or more distractor tasks, but not by the presence of a biasing factor (numerical score). Spatial versus non-spatial audio without a distractor task (blocks 9, 10) indicated no significant advantage for target acquisition. Contrasting this, attentional tunneling to the perceived requirement to perform as well on the distractor task as on the target acquisition task likely caused momentary allocation of perceptual resources to the distractor at times when the target was present. This allocation occurred despite the advantage of allocating resources between different modalities (visual, tactile, auditory)[18]. No significant differences were found due to the type of distractor task, even for the combined task condition (blocks 11, 12); in all cases, spatially

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[15] Moran, B. (1991) Readback Hearback. ASRS (Aviation Safety Reporting System) Directline, issue 1; retrieved from https://asrs.arc.nasa.gov/publications/directline/dl1_read.htm
[16] Begault, D.R. (1998) Virtual acoustics, aeronautics and communications. *Journal of the Audio Engineering Society*, 46, 520–530.
[17] Begault, D.R., Sunder, K., Godfroy, M., and Otto, P. (2015) Speech Intelligibility Advantage using an Acoustic Beamformer Display. *Audio Engineering Society 139th Convention, New York, NY.* Engineering Report 211.
[18] Wickens, C. (2002) Multiple resources and performance prediction. *Theoretical Issues in Ergon Science* 3:2, 159–177.

differentiating the location of one's own call sign provided a reduction in missed targets compared to the single channel condition.

No significant effect for timing of responses was found across all conditions tested. Also, a very low rate of false alarms was found. This indicates a high level of motivation on the part of participants to perform the task as quickly and accurately as possible, as per their instructions (ref. Appendix A).

This study represents the first of a two-part investigation. In this first study, the background noise was constant, simulating the acoustic condition of aircraft in cruise mode (e.g., ~33,000 ft. altitude, no elevation deviation, turbulence, or weather). The literature concerning non-auditory effects of noise has indicated that the ability to focus attention on a task such as target identification is easier under constant noise than with intermittent or time-varying noise[19]. A second between-subjects study is underway that will repeat the experiment, but with the background noise designed to simulate random impulsive events, simulating potential sounds in an off-nominal situation of engine or structural failure of the aircraft. The potential advantage of spatial audio presentation in off-nominal situations may or may not be more pronounced in this scenario.

[19] Begault, D.R. (2018) Assessment and Mitigation of the Effects of Noise on Habitability in Deep Space Environments: Report on Non-Auditory Effects of Noise. NASA Technical Memorandum 2018–219748.

Appendix A. Subject Consent Form, Instructions

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

SUBJECT CONSENT FORM (Attention experiment 2017)

Please read completely:

Research in the NASA Ames Advanced Controls and Displays Lab is considered "minimal risk." You will be asked to view computer-generated graphics and listen to computer-generated sounds. You are then asked to touch specific buttons or adjust a virtual knob on an iPad. In some cases you will see a score that increases with each correct response. The experimental task is very much like a computer game. **Accuracy** and **response time ("speed")** in response to hearing and seeing the stimuli will be measured. **Your responses to different types of stimuli are equally important.**

The graphics will be presented at a comfortable brightness level on a flat panel "iPad" display. The sounds will be presented at moderate sound levels via loudspeakers.

During the experiment, you will run 15 blocks, each 10 minutes long. You will be asked to attend to both auditory and visual stimuli while performing these tasks:

(1) Touch a specific button on the iPad in response to hearing "United 972, climb...", "United 972, descend....," "United 972, turn right...." or "United 972, turn left."

(2) Touch a specific button on the iPad button when the word ALERT is presented

(3) Manipulate with your finger a virtual knob on a touchscreen to match an indicated instruction such as "Set knob to 270." The knob is a dial with a pointer and it ranges clockwise from 0-359.

Each of these tasks are not difficult to accomplish in themselves and will be reviewed prior to the experiment by running some short training blocks of 2 minutes each. You can ask questions during the training sessions, and the experiment proctor will confirm you are able to accomplish the task. The overall time will not exceed three hours.

The experiment takes place in our laboratory. Before beginning you will be asked to fill out a brief vision-heading questionnaire. In-between blocks, you will be asked to write down the final score you achieved after running the block on a pad of paper.

The purpose of this study is to understand human perception and performance in response to computer generated stimuli for aviation-related tasks of interest to NASA.

We will use your data **anonymously**, along with data from several other subjects. However, despite the measures to be taken to maintain the anonymity and preserve the confidentiality of participants, there is still a very small risk that participants' identity could become known.

Devices such as cell phones must be shut off while the experiment is running (but OK to use during breaks).

Your experiment proctor will be one of the following people: Giovanna Flores; Durand Begault (650) 604-3920, or ______________________. You may contact their supervisor Dr. Brent Beutter (650) 604-5150. If you were contacted for this experiment by SJSUF and will be paid by SJSUF, please call Kari Jordan of SJSUF (650) 604-5118 to cancel if you have any condition that might impair your visual, auditory, or manual performance, or if you have any other concerns.

The only potential discomfort you may experience is **fatigue** from doing a repetitive task that involves the arm/hand movements necessary for pushing buttons on an iPad. You may also experience fatigue from concentration on the tasks or listening to repetitive sounds. Please let the experiment monitor know if you want to take a break to stretch, get some fresh air, etc., at any time. The experiment monitor will be nearby and will check in with you from time to time.

Remember that your participation is entirely voluntary. **You have the right to leave the experiment room and quit the experiment at any time, without explanation.** (Of course, we hope you will finish all of the blocks, otherwise your data cannot be used!) The experiment monitor will be available to assist you in using or adjusting any equipment that you will be using for your particular experiment. Finally, we reserve the right to stop using you as a subject, for any reason. You will be paid for the time you have worked up to that point.

By signing below, you (1) give your consent to be a subject in this experiment, (2) understand this consent form, and (3) certify that you're at least 18 years of age and no older than 40 years of age.

Signature____ Date____________________

Name (printed)____